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Summer diet of *Podarcis milensis*, *P. gaigeae* and *P. erhardii* (Sauria: Lacertidae)

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Abstract. In the present study data on the diet composition of three non sympatric lacertid lizard species of the Aegean archipelago (Greece) are given. The stomach contents of 157 specimens of *Podarcis milensis* (62), *Podarcis gaigeae* (50) and *Podarcis erhardii* (45) were examined for prey remnants. All animals come from Museum collections and were sampled during summer. During this season, *Podarcis milensis* and *Podarcis gaigeae* show a quite similar diet, they both feed mainly on ants, Coleoptera and insect larvae while *Podarcis erhardii* preys on Coleoptera and Orthoptera. The results are discussed together with prey availability data.

Key words. Diet, *Podarcis*, island ecology.

Introduction

Several studies on the diet composition of small lacertid lizards of the genus *Podarcis* have shown that these lizards feed mainly on arthropods (Arnold 1987). In general, lacertids are opportunistic predators and variations in their diet composition reflect differences in prey availability (Arnold 1987) — for a different point of view see Diaz 1995. In the Mediterranean islands the trophic characteristics of *Podarcis* populations are mainly affected by the present ecological conditions (biotic and/or abiotic), even though in some cases historical factors seem to play an important role (Pérez-Mellado & Corti 1993).

In the Aegean archipelago, three species of the genus *Podarcis* are distinctly distributed: *Podarcis milensis* is an endemic species of the Milos islands group (Milos, Kimolos and surrounding islets), *Podarcis gaigeae* is an endemic of the Skyros islands group (Skyros, Piperi and surrounding islets), while *Podarcis erhardii* predominates in the rest insular ecosystems of the north, central and south Aegean.

The systematics and the distribution of the three species are well studied, however our knowledge of their ecology is quite insufficient, concerning only *Podarcis erhardii* (Valakos 1986, 1990). *Podarcis erhardii* feeds mainly on arthropods, with Coleoptera as the dominant prey group. Coleoptera also dominate in the spring diet of *Podarcis milensis* in small islets (Valakos et al. 1995). In the case of *Podarcis gaigeae* there are no data except some small notes (Gruber & Westrum 1971).

In this study, data on the food composition of the three species are presented and further discussed. All samples come from summer, a period which is characterized by low arthropod densities in the insular ecosystems of the Aegean (Karamaouna 1987).

Material and Methods

A total of 157 animals was examined. Specimens of *Podarcis milensis* (62 specimens from June & July, locality: Milos island) and *Podarcis gaigeae* (50 specimens from August, locality: Skyros island) come from the Herpetological collection of the Naturhistorisches Museum of Vienna and from the Museum "Alexander Koenig" (Bonn), while the samples of *Podarcis erhardii* (45 specimens from July, locality: Naxos island) belong to the Herpetological collection of the section of Animal and Human Physiology of the University of Athens.

For each animal we removed the entire digestive tract and examined it for the presence of prey remnants. Prey items were grouped to taxonomic categories, generally order level. Coleopteran and lepidopteran larvae were grouped in one category as "insect larvae".

In order to avoid biases in the evaluation of the diet, stomach contents were summarized in two ways: 1) relative abundance (%n) (proportion of the total number of prey items in the stomach, corresponding to a given prey type) and 2) relative incidence (F) (proportion of lizards eating a given prey taxon).

Trophic niche breadth was calculated according to Levin's standardized index (Krebs 1989):

$$B_A = \frac{B-1}{n-1}$$

where: B_A = Levin's standardized niche breadth
B = Levin's measure of niche breadth
n = Number of possible resource states

The diet overlap between allopatric populations was calculated using Pianka's formula (1973):

$$Q_{kj} = \frac{\sum p_{ik} p_{ij}}{\sqrt{\sum p_{ik}^2 \sum p_{ij}^2}}$$

where: Q_{kj} = Overlap
p_i = % of ith category of prey for species k and j.

Estimates of the availability of potential prey for *P. milensis* were obtained through the use of pitfall traps (without any baits). Ten pitfall traps were installed during July, in a typical biotope of *P. milensis* at Milos island. These traps were placed in two parallel lines, covering all the possible microhabitats occupied by the lizards. The trapped prey was identified at order level. In the case of *Podarcis erhardii* from Naxos island, data from the same locality and during the same period, Paraschi (1988), were used. These data were obtained from summer (July) pitfall traps in a typical ecosystem of Naxos island, where *P. erhardii* is the dominant lizard species. We have used pitfall traps in order to obtain a general picture as all species are ground-dwelling (Valakos 1990; Gruber & Westrum 1971), although we are aware of the potential biases introduced by the pitfall-based method for measuring prey availability (Pérez-Mellado et al. 1991).

Electivity for a food category was calculated with Ivlev's (1961) index:

$$E = (ri-pi) \;/\; (ri+pi)$$

based on the proportions of prey category in the diet (ri) and in the habitat (pi).

The water contents of insect larvae were estimated using the lyophilize method. Nine (9) Tenebrio larvae were lyophilized using the Labconco Freezedry System / Freezone 4,5.

Results

Composition of Diet

Table 1 summarizes the diet of the three species. There is a significant relation between the proportion of the total number of prey items in the stomach (%n) and the proportion of lizards eating a prey taxon (F), (Spearman test, $P<0.05$), in all three species.

Podarcis milensis feeds mainly on ants, Coleoptera and insect larvae. The same groups predominate in the diet of *Podarcis gaigeae*, while Coleoptera (the second

Table 1: Dietary data obtained from 157 Museum specimens of *P. milensis, P. gaigeae* and *P. erhardii*. % n: proportion by number of items, F: frequency of occurrence.

Prey		*P. milensis*			*P. gaigeae*			*P erhardii*	
	n	% n	F	n	% n	F	n	% n	F
Araneae	16	9.46	3.22	8	3.1	16	17	8.67	33.33
Pseudoscorpiones	1	0.59	1.61	2	0.8	2	1	0.5	2.22
Solifugae	1	0.59	1.61						
Acari	1	0.59	1.61	1	0.39	2			
Diplopoda				1	0.39	2			
Isopoda	2	1.18	6.45	4	1.55	8			
Collembola	2	1.18	1.61						
Dermaptera	2	1.18	3.22						
Mecoptera				1	0.38	2			
Hemiptera	18	10.6	27.42	11	4.24	22	15	7.65	33.33
Hymenoptera	4	2.36	16.13	9	3.49	14	8	4.08	17.7
Diptera	15	8.87	20.96	3	1.16	6	4	2.04	6.66
Ants	40	23.66	45.16	156	60.46	58	19	9.69	26.6
Coleoptera	20	11.83	51.61	25	9.69	36	52	26.53	73.3
Mantodea							4	2.04	6.66
Blattodea							1	0.5	2.22
Lepidoptera							1	0.5	2.22
Neuroptera							1	0.5	2.22
Trichoptera	2	1.18	6.45						
Embioptera	4	2.36	3.22						
Orthoptera	13	7.68	20.96	9	3.49	16	45	22.95	68.8
Isoptera	3	1.77	1.61						
Gastropoda							19	9.69	35.5
Insect larvae	27	15.97	30.64	17	6.58	22	9	4.59	20
Plant material	1	0.59	1.61	9	3.49	18			
Cannibalism				2	0.78	4			
No. of prey items	169			258			196		
No. of liz. exam.	62			50			45		

group is Orthoptera) are the most common and frequent prey in the stomachs of *Podarcis erhardii*. Plant material and cannibalism have been observed only in the case of *Podarcis gaigeae* (Table 1).

The trophic niche breadth of the three species is low according either to %n (*Pm*: $B_s=0.386$, *Pg*: $B_s=0.113$, *Pe*: $B_s=0.404$) or to F (*Pm*: $B_s=0.409$, *Pg*: $B_s 0.475$, *Pe*: $B_s=0.480$).

The overlap values between *Podarcis milensis* and the two other species are relatively high (Pm–Pg: $Q_{jk}=0.787$, Pm–Pe: $Q_{jk}=0.678$), while *Podarcis erhardii* and *Podarcis gaigeae* show a lower overlap value (Pe–Pg: $Q_{jk}=0.415$). The diet of the examined populations showed significant differences in the proportions of the prey items consumed (Chi-square test: Pm–Pg: $x^2=44.27$, d.f.=19, $p<0.05$, Pm–Pe: $x^2=52.73$, d.f.=19, $p<0.05$ and Pe–Pg: $x^2=30.21$, d.f.=18, $p<0.05$).

Food availability and electivity

In Fig. 1 the electivity values and the relative abundance of arthropods in the traps of Milos island are given (only the taxa that participate in the food of the lizards are presented). Ants, Coleoptera, and spiders were the most abundant groups. Electivity values for these groups are negative or close to zero. For insect larvae, Hymenoptera, Hemiptera, Diptera, Orthoptera the electivity values were high. The representation of these taxa both in the traps and in the lizard's diet was relatively good. There is a significant negative correlation between the electivity of prey taxa and their relative abundance in the traps.

In the case of Naxos Island ants and spiders were the most abundant arthropods while their electivity values were negative (Fig. 2). Coleoptera, Orthoptera and insect larvae have high electivity values though their representation in the traps was low. There is negative but not significant correlation between the prey electivity values and their corresponding relative abundance.

Discussion

The diet of the examined species is composed by arthropods. Arthropods are the major food of *Podarcis* species in the Mediterranean islands (e. g. Valakos 1986, 1987; Pérez-Mellado & Corti 1993).

All species mainly are widely foraging predators, similar to the majority of lacertids, as they consume many different types of prey like several sedentary animals (snails, pseudoscorpions, insect larvae, isopoda, etc.) (Huey & Pianka 1981).

Previous studies made on the diet composition of *Podarcis milensis* during spring, in small islets, have shown that arthropods were the major prey of the animals, even though the predominant groups in the stomachs were insect larvae, Coleoptera, Diptera, Gastropoda and Araneae (Valakos et al. 1995). On the other hand, during summer, *Podarcis milensis* in Milos island seems to have a different diet, although some groups are still the same. Such regional and seasonal differences have been observed also in other island populations in the Mediterranean (Pérez-Mellado & Corti 1993; Pollo & Pérez-Mellado 1988).

Regarding *Podarcis gaigeae*, these first data indicate a remarkable presence of ants in its summer diet.

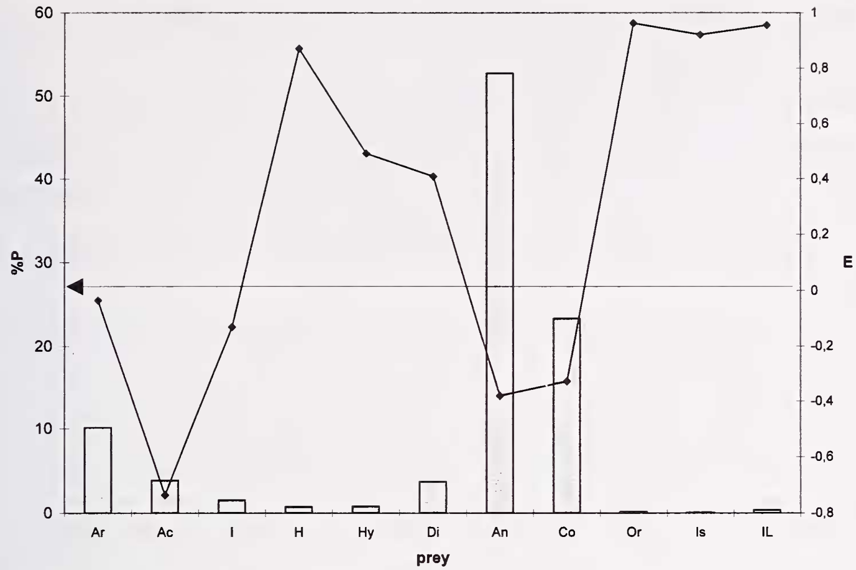

Fig. 1: Relative frequency (columns, %) of prey categories in the environment of *Podarcis milensis* (results from pitfall traps) and electivity (black squares) values. Ar: Araneae, Ac: Acari, I: Isopoda, H: Hemiptera, Hy: Hymenoptera, Di: Diptera, An: Ants, Co: Coleoptera, Or: Orthoptera, Is: Isoptera, IL: insect larvae, Ps: Pseudoscorpiones.

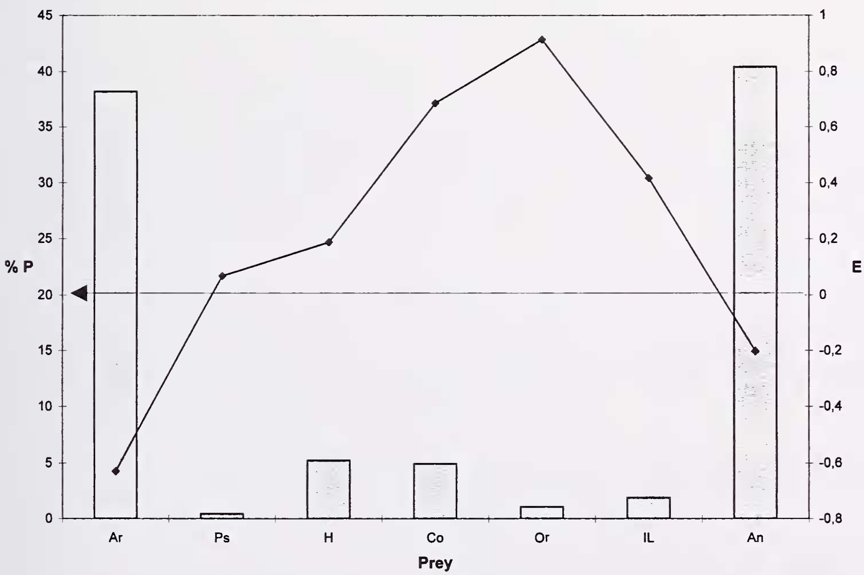

Fig. 2: Relative frequency (columns, %) of prey categories in the environment of *Podarcis erhardii* (results from pitfall traps) and electivity (black squares) values. Abbreviations as in figure 1.

Coleoptera seem to be the most common prey for *Podarcis erhardii* during summer and spring, though seasonal differences in its diet have also been mentioned (Valakos 1986, 1990; Valakos et al. 1995).

The low niche breadth during summer seems to be related to the poor trophic availability. During summer the density of arthropods in the insular ecosystems of the Aegean is very low (Karamaouna 1987; Paraschi 1988). During spring *Podarcis erhardii* has a wider niche breadth in the same ecosystem (Valakos 1990; Valakos et al. 1995). Similar decrease of the niche breath between spring and summer was also mentioned in *Podarcis lilfordi* in the Mediterranean (Pérez-Mellado & Corti 1993).

Like other insular populations of *Podarcis*, the three species often feed on clumped prey such as Hemiptera and ants. These groups are dominant during summer in this type of ecosystems (Paraschi 1988). The presence of the ants in the diet of the examined species seems to be associated to environments with poor trophic availability. Myrmecophagy is common among insular populations of *Podarcis* lizards (Quayle 1983; Ouboter 1981; Pérez-Mellado & Corti 1993) as an optimal strategy in arid environments or arid conditions (Pianka 1986; James 1991). Likewise the choice of clumped prey is supposed to be a good strategy in arid environments because it either minimizes the searching cost (Pollo & Pérez-Mellado 1988, 1991) or minimizes the predation risk (Schoener 1969).

The negative significant correlation of the relative abundances of prey groups in the traps, and the electivity values, in the case of *Podarcis milensis* and the non-significant correlation in the case of *Podarcis erhardii* indicate that diet composition may not be a simple reflection of the trophic availability as it results from our traps (Pérez-Mellado et al. 1991; Diaz 1995) although prey availability estimates could be biased because of the sampling method. Some prey groups (e. g. Coleoptera, Hemiptera etc.) are selected by the lizards, though their relative abundance in the traps is low. This indicates that lizards attempt to maintain a balanced diet, as imposed by the demands of minimal amounts of certain nutrients (Pérez-Mellado et al. 1991). All species seem to select insect larvae during summer although their presence in the traps is low. This preference seems to be related with their high content in water. Insect larvae contain more than 50 % water (Roots 1978). In Table 2 the statistics of the dry and wet weight of 9 larvae of *Tenebrio* are given. The water content ranges from 61 % to 82 %. Insect larvae were absent from the diet of *P. peloponnesiaca* which distributes in Peloponnisos with more wet climatological conditions (Maragou et al. 1995, 1996). Nevertheless, one could argue that insect larvae are preferred because of their nutritive content or because they lack chitinization. Still, more studies need to be done on the nutrient contents of the different

Table 2: Statistics of dry and wet weight of nine *Tenebrio* larvae.

	X (mean)	S. D.	min	max	N
Wet weight (gr)	0.14	0.031	0.1	0.2	9
Dry weight (gr)	0.41	0.018	0.018	0.078	9
% difference	71.5	7.09	61.9	82.14	9

arthropod groups for the determination of the importance of nutrient constraints in lacertid lizards (Pérez-Mellado et al. 1991). It must be noted that the comparison between stomach contents from Museum specimens and data from field traps could lead to inconsistent conclusions. However, the results can be viewed as a general approach, especially since for at least *P. milensis* and *P. gaigeae*, the foraging strategy is insufficiently known. Moreover, a comparison between the stomach contents of Museum specimens from Milos and lizards caught at the same area as the traps, revealed no significant differences (Adamopoulou, unpublished data).

Pérez-Mellado & Corti (1993) mentioned a case of herbivory in *Podarcis* species in the Baleares, attributed as adaptation of dense populations inhabiting very old isolated islands (Messinian) with very poor trophic resources. About 18 % of the examined specimens of *P. gaigeae* had consumed plant material, however these plant matters never represented a substantial fraction of the food volume. This fact indicates that plant material was probably accidentally consumed together with the prey, thus, can be regarded as additional food eaten sporadically (Castilla et al. 1991).

The similarity values between the examined populations seem to denote that the prey selection of the *Podarcis* species in the Aegan archipelago is affected by the present ecological conditions like the majority of the insular Mediterranean populations.

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Zusammenfassung

Die vorliegende Studie behandelt die Nahrungszusammensetzung dreier nichtsympatrischer Eidechsenarten von den Ägäischen Inseln, Griechenland. Der Mageninhalt von 157 Exemplaren von *Podarcis milensis* (62), *Podarcis gaigeae* (50) und *Podarcis erhardii* (45) wurde auf Beuterückstände untersucht. Alle Tiere kamen aus Museumssammlungen und waren im Sommer gefunden worden. In dieser Jahreszeit nehmen *Podarsis milensis* und *Podarcis gaigeae* ähnliche Nahrung auf, hauptsächlich Ameisen, Coleoptera und Insektenlarven, während *Podarcis erhardii* Coleoptera und Orthoptera erbeutet. Die Ergebnisse werden im Zusammenhang mit der verfügbaren Beute diskutiert.

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